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COPY 181

THIS DOCUMENT contains 51 Pages
Copy No. 6 of 20 Pages Series A

TECHNICAL PROPOSAL
for

A SIMPLIFIED, HIGH-ACUITY PANORAMIC CAMERA

Jim

BT-1943
Prop Sec

19 DECEMBER 1961

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CONTENTS

FIGURES

TABLES

1. INTRODUCTION

Itek herewith submits the following proposal for continuing the development of a high-acuity, panoramic camera for fulfilling the need of a 4-to 5-foot resolution, recoverable satellite reconnaissance system at large image scale (1:125,000) in stereo without the former complexities of the E-5 camera recovery. This will result in overall camera simplification, increased reliability, improved performance, and overall economy.

The proposed camera will retain the essential features utilizing E-5 camera hardware and offering improved photographic performance over E-5 in a new structural configuration involving film recovery only. It is assumed that this camera can complement the E-6 in fulfilling intelligence objectives utilizing the common Atlas/Agena B launch vehicle and the identical E-6 recovery capsule or possibly utilize a Thor/Agena B and another available recovery capsule if the weight can be reduced sufficiently.

Reinstitution of the Agena B vehicles from the 101B program without LMSC weapon system responsibilities will enable a substantial overall cost reduction. In addition, making common use of another recovery system, i.e., either the E-6 recovery package or similar already developed capsule will result in additional overall economies. If the system is configured for launching using a Thor rather than Atlas booster, an additional major economy of both booster cost as well as launch operations will result.

From our experience in the 101B program, Itek is convinced that the concept of assigning overall program management to a prime contractor — with the subcontractor participation reduced to the role of vendor — is now generally acknowledged to be an abortive procedure when applied to a system such as E-5.

We are therefore proposing a program which, in addition to making maximum utilization of the state-of-the-art advances achieved in the E-5 camera.

assures a strong, well-directed program performance by adoption of the integrated management approach implicit in the concept of SETD organization. The effectiveness of this approach has been demonstrated in numerous missile programs.

From the foregoing it would appear that the proper contract-management relationships for the proposed program are those which would result from assigning co-equal responsibilities to the contractor for the launch vehicle, the camera payload, and the recovery capsule. This basic division of responsibilities would be supplemented by a firm definition of functions and responsibilities for all parties, with either USAF or Aerospace Corporation providing SETD. It is Itek's firm belief that this integrating influence is of vital importance in eliminating the lack of decision, vacillating policy, complexity of organization, rapid turnover of key personnel, heavy visitor loads, and overwhelming personnel-familiarization requirements which characterized the E-5 development.

Other advantages deriving from the SETD approach are: (1) the elimination of delays resulting from the lack of good lateral communication and, at best, poor vertical communication, and (2) the directness with which the contracting agency can assess joint contractor performance and eliminate inter-contractor confusion over contract schedules and objectives.

Itek predicates their proposal on the formulation of the SETD approach and will establish the management/technical team on a complementary basis. We further assume the feasibility of transferring applicable items (of the inventory at Itek, LMSC, and the various subcontractors) to the proposed effort. We propose that the complete responsibility for the use of the G. F. P. Dynamic Resolution Testers at Itek, Lexington and at LMSC, Sunnyvale be given to Itek Laboratories. This provision would assure the all-important continuity of technical familiarity with the reconnaissance instrument from fabrication to launch. Completed cameras would be shipped from Itek, Lexington, receive final camera checkout by Itek, Palo Alto, field-service personnel, using the Sunnyvale DRT, and be mated to the Agena B vehicle and given system test. The proposed program organization at Itek Laboratories is shown on the following page.

We feel that the proposed program makes frank recognition of the exigencies lying behind the recent termination of the E-5 program while, through the course of action indicated above, suggesting a future line of approach which promises the maximum recovery to the U. S. government of its considerable E-5 investment, and our continued involvement in a program having vital importance to the national welfare.

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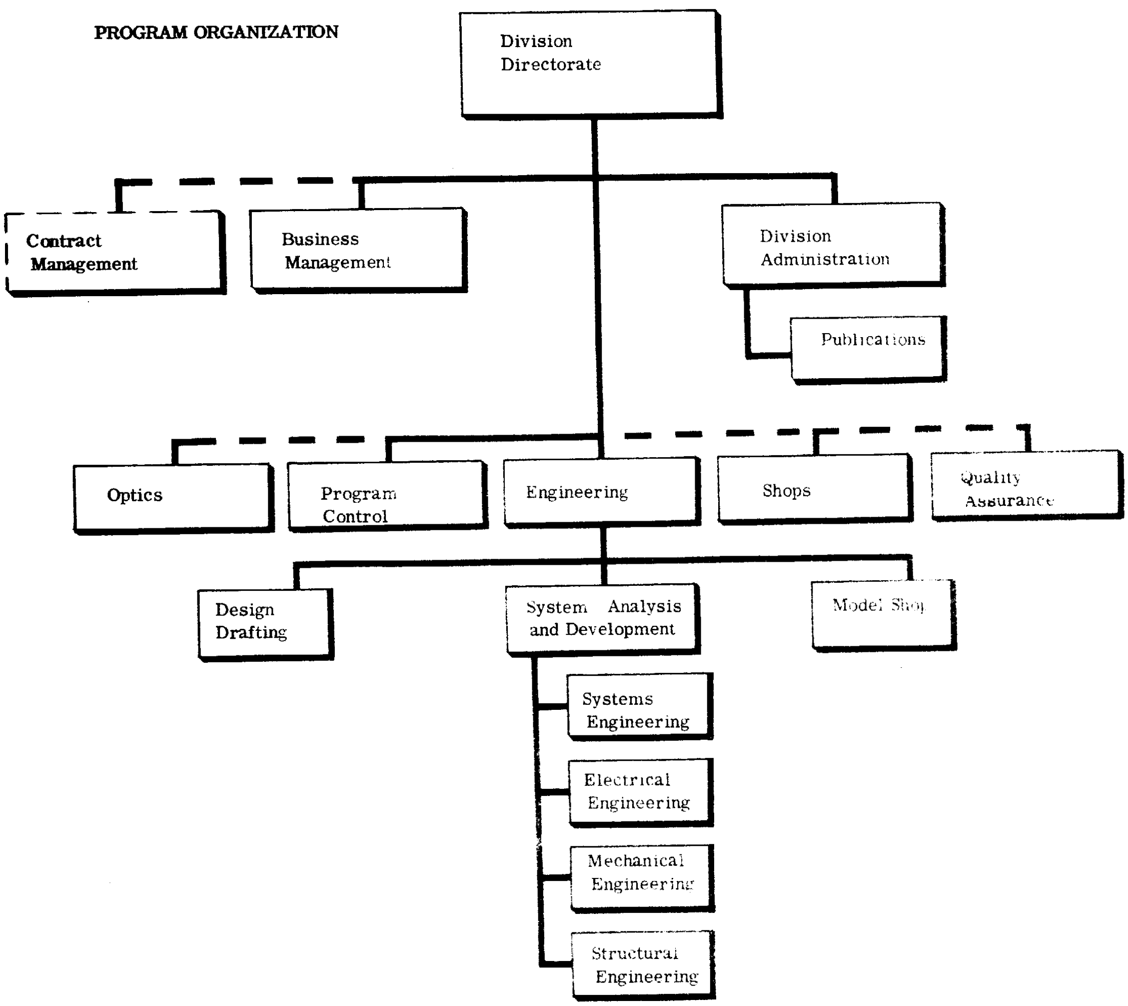
PROGRAM ORGANIZATION



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2 TECHNICAL APPROACH

The principle objective of the proposed program is to produce a camera which will provide the most reliable means for fulfilling E-5 intelligence objectives without compromising the reconnaissance mission through use of a configuration involving the recovery of the entire camera to provide a build-up for a Man-in-Space recovery capsule. Ground resolution, operational period and latitude coverage, and other mission parameters are summarized in Tables 1 and 2. A secondary objective is to provide for inclusion of improved optics which can be retrofitted when available. The short delivery time postulated for the flight prototype and the desirability of effecting maximum economy dictates use of present hardware, including the existing E-5 lens.

The photographic performance capabilities and reliable camera operation of the E-5 camera have been demonstrated in the laboratory on units already delivered. A complete detailed status summary of these units is included as Appendix A.

Test results on the 02 and 03 units indicate a predicted operational resolution on SO-130 film of 45 L/mm for the 02 November flight and 50 L/mm on 03 for the December flight. The predicted operational resolution for the remaining E-5 cameras is projected to 100 L/mm on a progressive basis, based on measured improvements in the 05 lens performance, the predicted improvement in 06 and up, the increase in illumination from December to June flights (allowing the use of shorter exposure times for SO-130 film and allowing the use of SO-132 film) improved electromechanical operation, reduction of internal camera vibration, and refined testing techniques based on knowledge and experience gained from testing each unit.

The soundness of the E-5 camera design has been demonstrated by the inherent reliability of units already built and tested: The 02 unit was subjected to extensive ground-tests (approximately 10 to 15 times mission life) without

Table 1 — Latitude Coverage, Ground Resolution, and Operational Period for 100- and 132-Nautical Mile Altitude at Both 8:1 (Medium) and 2:1 Contrasts at Local Noon

		Ground Resolution, ft*			
		8:1 Contrast		2:1 Contrast	
		Altitude, n. mi.		Altitude, n. mi.	
Latitude, °N.	Operational Period	100	132	100	132
Up to 35	8 months	3	4	4	5
	All year	3 ½	4 ½	4 ½	6
Up to 55	4 months	3	4	4	5
	6 ½ months	3 ½	4 ½	4 ½	6
	All year	4	5	5	6 ½
Up to 70	1 month	3	4	4	5
	4 months	3 ½	4 ½	4 ½	6
	8 months	4	5	5	6
	All year	6	8	7	9 ½

*AWAR over 5-inch film width as measured with E-5 Lens (06) peak performance would obviously be higher resolution as seen in Appendix B.

Table 2 — Mission Parameters

Film Capacity:
150 pounds (approximately 17,000 feet) to 250 pounds (28,200 feet) depending on coverage desired and recovery capsule selected

Mission Duration:
4-5 to 8-9 days depending on film capacity

Film:
5 inches 2½-mil Estar Eastman Kodak SO-130 and SO-132 for year-round flights

Altitude:
100-132 nautical miles depending on mission duration

Optics:
66 inches f/5 Itek Triplet Lens (101B S/N 06) 28-inch diameter aluminum mirror

Ground Cover per Photograph:
38-50-nautical mile swath over altitude range
6-8-nautical mile along flight path over altitude range

Overlap:
10 percent minimum at nadir

Ground Coverage:
3-5 million square nautical miles

Roll Steering:
±30 degrees of vehicle roll to provide for specific objective targeting

Stereo:
30 degrees fore and aft stereo convergence

a major camera-system failure; the 03 unit, which has yet to be flown, has accumulated ground-test time equivalent to 5 to 10 times normal mission life without a major failure; the 04 unit is undergoing similar ground testing showing major performance improvement. Work on units 05 through 09 has been stopped by termination, although most of the parts are on hand, and indeed a majority of subassemblies are assembled.

Therefore, Itek feels that the following modification program will result in a short-time delivery of a camera system that will satisfy mission objectives with proven performance and reliability.

The proposed modification program will be carried out in three phases:

Phase I — System Design Study

Phase II — System development leading to the delivery of a flight prototype camera in September 1962 for a late-fall flight

Phase III — Fabrication and delivery of four additional units at 6-week intervals

The Program Schedule for the proposed effort is included at the end of this section.

2.1 PHASE I — SYSTEM DESIGN STUDY

The proposed design study will result in a camera which will retain the photographic features and offer improved performance capabilities. The ultimate product of the system study design will be a camera design configuration leading to a prototype flight unit scheduled for delivery in September of 1962.

In addition, an evaluation and test program will be conducted on existing components and subassemblies to demonstrate performance of the improved design and confirm their operability in vacuum. The design study will define and resolve interfaces pertaining to the LMSC vehicle and the selected recovery capsule.

In addition, other lens designs will be investigated and evaluated, including a 66-inch, f/5, long-barrel, improved triplet and an increased aperture triplet of f/4.5 or f/4.

At the end of the study, a design layout will be completed. The structural drawings will be frozen and ready for release to previously selected vendors for fabrication of a structural mockup; life tests in the anticipated environment will have been performed, and functional tests on laboratory mockups will be completed on essential new components.

2.2 PHASE II — DEVELOPMENT PROGRAM

The deliverable camera will be a flight prototype, designed and produced in a very short time span which prohibits the elaborate drawing requirements, extensive redirection, and elaborate engineering and quality control monitoring imposed by the previous weapon systems concept on E-5. To expedite such a program, the following procedures would be observed:

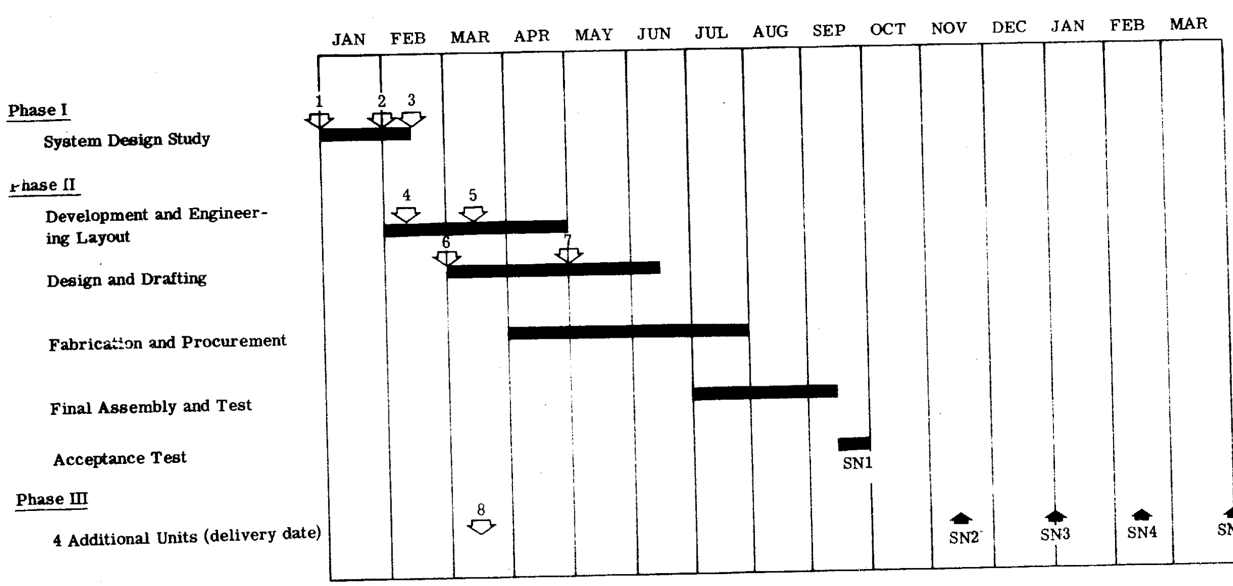
1. Itek drawings and bills of material would be complete and suitable for manufacture. Assembly and subassembly drawings would be at Itek's discretion.
2. Mil-spec components would be used where possible.
3. Normal quality control will be exercised by Itek Quality Assurance to assure highest standards of workmanship and performance.
4. Purchasing practices would be streamlined for fast reaction.

The development program will result in a complete set of engineering drawings and specifications adequate for manufacture of subsequent units together with delivery of a flight-prototype camera which has passed engineering and manufacturing tests and is ready for acceptance. In addition, by fabricating and environmentally testing a structural mockup with dummy loads, the new camera structure will be flight qualified. All E-5 subassemblies to be used have satisfactorily met flight requirements.

2.3 PHASE III — FABRICATION AND DELIVERY

Provided that additional units are ordered with sufficient lead time (i. e., approximately 8 months), an additional 4 units may be delivered at 6 week intervals.

Program Schedule



1. Start design study
2. Design configuration review and approval
3. Design study final report
4. Interface definition
5. Design freeze
6. Long lead items released
7. 95% parts released
8. Order for production of 4 additional units

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3 TECHNICAL DISCUSSION

3.1 PROPOSED CAMERA SYSTEM

The proposed camera system is essentially an adaptation of the photographic subsystems of the E-5 system repackaged in a new structure that allows the use of a film-recovery capsule. Fig. 1 shows the present E-5 recovery capsule in phantom on the LMSC Agena-B vehicle. The film-recovery capsule is shown in the nose of the new camera configuration, which is approximately the same length as E-5. The film-recovery capsule is supported by the camera structure which is mounted to the Agena-B interface. The proposed structure is unpressurized, and the camera will operate in a vacuum environment using passive-radiation thermal balance for temperature stabilization. (The pressurized system had been used on the E-5 camera, principally for camera re-entry structural stiffness.)

The E-5, 66-inch, f/5 lens is shown in the existing oscillating lens drive assembly and the present E-5 mirror and stereo drive are shown in front of the lens, thereby permitting ground viewing through an opening in the side of the camera structure.

With the elimination of the pressurization system the present E-5 vacuum platen shutter may not be used. To ensure that the film is properly located against the platen surface film-holding rollers will be used. These may be attached to the lens, as shown, on a scanning arm establishing the precise focal plane and resulting in a simplified system. The focal plane shutter mounts will be adjacent to the film providing for image exposure while the lens scans across the flight path in one direction, and providing for capping on the return stroke.

The take-up spool is shown located in the recovery capsule. The supply spool is shown supported by the camera structure and located close to both the platen and the take-up spool, thereby providing a simplified film path. The proposed film-transport system will utilize existing subassemblies the present E-5 film-transport system.

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Fig. 1 – High-acuity, pa[redacted]ra – configuration 1

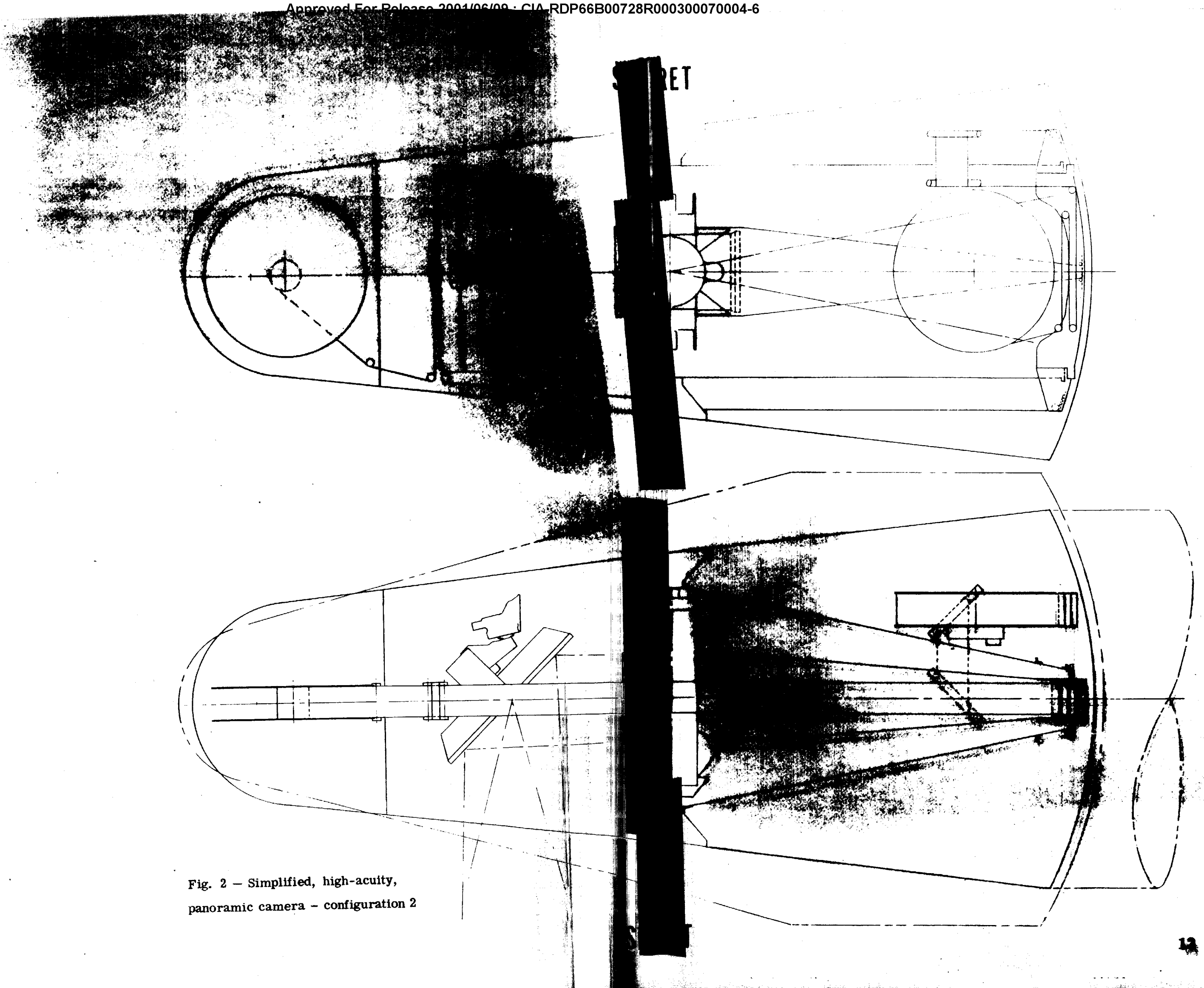

Fig. 2 – Simplified, high-acuity, panoramic camera – configuration 2

Utilization of a recovery capsule containing only the exposed film, as opposed to the recovery of the entire camera in the E-5 system, permits the use of film spools of reduced diameter with a capacity of 150 to 250 pounds of 2 1/2 mil Estar film enough for a 4- to 9-day mission. The spools are counter-rotated about the yaw axis. With the smaller spools, the total change in angular momentum is sufficiently small to eliminate the requirement for momentum balancing.

Fig. 1 also shows a 27-inch long, 66-inch, f/5 lens of improved performance. This longer lens barrel may be field-retrofitted into the modified camera should it become available in time.

In summation, it can be said that this configuration has a compact film-transport system and locates the heavier elements of the camera as far aft as possible, close to the Agena mounting interface for minimum structure weight.

Fig. 2 depicts a configuration which would permit the use of a wider scan angle, thereby offering the possibility of eliminating roll-steering of the vehicle and the camera IMC cam. The operational requirement of roll steering would have to be evaluated and compared to the use of a wider scan angle. However, the film path would be longer and the distribution of subassemblies would create additional structural problems. Weighing the relative advantages and disadvantages of the two proposed configurations, that shown in Fig. 1 appears to be preferable.

3.2 COMPARISON OF PRESENT E-5 AND PROPOSED SYSTEM RECOVERY

The E-5 system involves recovery of the entire camera, including film, whereas the proposed system involves the recovery only of exposed film in an E-6 or equivalent recovery capsule already developed.

In the E-5 system, the first step upon completion of the photographic portion of the mission is to increase pressurization in the camera capsule from 7 to 10 pounds in order to stiffen the structure to meet re-entry requirements. The Agena is then reoriented and the engine is ignited in order to effect ejection from orbit. The mirror is jettisoned, and the lens is retracted to improve the center of gravity re-entry conditions. A re-entry window cover is closed to prevent it from severe heating which would result in window breakage and loss of pressurization. The entire camera/ recovery capsule is then separated from the orbit vehicle, the fairing doors are opened, the drogue gun is fired, and the drogue parachute deployed. The drogue and midbody fairings are then jettisoned, followed by deployment of the main parachute. The ablation shield is then jettisoned and the water impact bags inflated. This sequence involves thirteen major events, including five capsule component separations, if ejection of the launch nose fairing is counted.

By contrast, recovery of only the film capsule involves merely the reorientation of the Agena vehicle without restarting the Agena-B engine. (Elimination of the requirement for engine restart will enhance the total system reliability, as evidenced by recent experiences with the Ranger program, where Agena B orbit was achieved, but failure to restart the engine aborted the deep space mission.) At this time the film is severed and the film gate sealed, the recovery capsule is separated from the camera, and a more reliable solid retro rocket is fired to effect ejection from orbit. The drogue parachute is deployed and jettisoned and the main chute is deployed. This sequence comprises a total of seven major events and only two capsule component separations, including jettisoning of the viewing hatch when orbit is achieved.

The increased reliability of the simplified sequence, and the avoidance of duplicating development and continued operations of both an E-5 and E-6 type of recovery system, should result in major overall economies.

3.3 COMPARISON OF PRESENT E-5 AND PROPOSED CAMERA

The following sections provide a detailed comparison between the present E-5 camera and the proposed camera. As shown, of 22 major subsystems and assemblies, 10 are identical, 7 are completely eliminated, and the remaining 5 are simplified. The degree of simplification is readily seen on the E-5 electrical functional schematic diagram (Fig. 3) where eliminated subsystems are marked out. This will result in the new camera having only

ILLEGIB [redacted] of the E-5 electronics in modular form resulting in improv- [redacted] workmanship, and overall reliability.

[redacted] Pressurized to reinforce structure against re-entry as dictated by camera recovery requirement.

Modified E-5. Open, permitting a passive thermal radiation, balanced system, eliminating an active environmental control system, image degrading air turbulence, and providing increased reliability by elimination of dependence on pressurization system.

The modified structure provides substantial improvements over the E-5 structure. The following are a few of the new features:

1. Complete accessibility to all subassemblies through fabrication, checkout and launch pad
2. Simplified camera assembly, offering schedule improvements
3. Simplified camera checkouts
4. Simplified structure fabrication
5. Lighter weight
6. The possibility of pad loading of flight film

These innovations are made possible chiefly by the elimination of the recovery requirements from the payload-capsule combination. Recovery conditions imposed design conditions for about 90 percent of the E-5 structure.

The modified structure no longer supports its contents and the additional heavy outer recovery capsule through the high accelerations encountered during re-entry, parachute and impact phases. Attachments and carry-through structure for drogue gun and main parachute for the combined weight of payload and outer capsule are not required with the subsequent deletion of the high internal pressurization previously required to withstand recovery loads.

Because it no longer has an outer capsule, the new modified structure can (A) assume a more efficient external shape with more space in critical areas, and (B) provide vastly greater accessibility to all vital internal components and systems.

3.3.2 MV Balance

Present E-5. Two linear-motion, servo-driven counterweights on ball screws, to counterbalance moment generated by IMC translations of the lens about the vehicle center of gravity.

Modified E-5. None required, eliminating two servos and thereby increasing reliability, reducing weight, decreasing power, and eliminating a major vibration source

It will not be necessary to balance the linear momentum resulting from lens IMC motion, provided the pitch channel of the Agena-B attitude stabilization system can be made to ignore rate inputs below 2 milliradians per second at the lens drive frequencies to prevent unwanted gas loss.

The elimination of momentum balance will require an IMC cam with a surface modified to correct for the image motion induced by the vehicle pitch rate. This vehicle pitch rate is induced by the lens driving vertically during the photographic portion of the scan cycle. The required cam surface for geometric compensation, including the predictable rate, is flat to within 0.0007 inch. Therefore, a simple flat cam of slightly different slope than the current E-5 cam can be used.

A possible source of IMC error which would arise from elimination of the MV system is the uncertainty in knowing vehicle/payload pitch inertia at the time the cam is cut, and variation in pitch inertia due to transporting the film from one spool to the other during flight. An estimated $\pm 2\frac{1}{2}$ percent variation in pitch inertia due to film transport plus a $\pm 2\frac{1}{2}$ percent uncertainty in predicting inertia at the time the cam is made will only increase estimated total image blur velocity from 660 ft/sec to 665 ft/sec which would be negligible.

The main effect of eliminating the MV balance would be the influence on the LMSC stabilization system in terms of allowable gas loss and the ability of LMSC to readily change the system to accommodate an unbalanced moving lens and still maintain required attitude control of the vehicle for high resolution performance. This area will be carefully investigated during the study. Originally, the E-5 had a 30-day mission requirement utilizing solar arrays. The array structure dictated the need for MV balance. Re-evaluation for elimination offers simplicity, a major weight and power saving, and decrease in a major internal vibration source of the camera, which will improve resolution.

3.3.3 I ω Balance

Present E-5. A servo-driven flywheel commanded by a spool-velocity summing device was required by the large-diameter spools on the roll axis. The spools had to be placed on the roll axis due to camera recovery center of gravity requirements and configuration.

Modified E-5. Iω balancing not required provided the spools are counter-rotating on either the pitch or on yaw axis. Vibration is eliminated, power consumption and weight reduced.

It will not be necessary to balance the angular momentum of the film spools in the proposed configuration since the spools rotate about the vehicle yaw axis which has a relatively large inertia and the axis about which the camera is least sensitive. The allowable vehicular rates are: roll and pitch - 30°/hr, yaw - 180°/hr.

With the spools counter-rotated, maximum angular momentum induced on the vehicle yaw axis at time of camera film transport startup will be less than 2 foot-pound-seconds, giving rise to a vehicle yaw rate of 48 degrees per hour in the worst case. This gives rise to an IMC error varying from 35 feet per second at maximum scan angle down to zero at nadir. This is a negligible amount of uncompensated image motion.

The other affect on the vehicle of not balancing spool angular momentum is to produce a roll moment through coupling of the spool yaw angular momentum with orbital pitch rate. The average magnitude of this moment throughout the mission is approximately 0.001 foot-pounds. Assuming a total of 4 hours of spool operation and a 2-foot roll jet moment arm on the Agena B results in a total mission impulse of 8 pound-seconds from the Agena roll stabilization jets. This is equivalent to less than 1 pound of propellant. Elimination of the Iω balance will save weight, reduce power consumption, and eliminate a major vibration source, thereby improving resolution without causing excessive gas loss.

3.3.4 Film Transport

Present E-5. Constant speed, constant tension, integrated dancer loop and semi-sinusoidal intermittent metering, insensitive to alignment.

Modified E-5. A simplified version of above since requirements for maintaining minimum torque reactions are greatly reduced by having smaller spools on either the pitch or yaw axis compared to the E-5 roll-axis configuration dictated by camera recovery requirement.

3.3.5 Shutter Platen

Present E-5. Two-curtain, focal-plane shutter servo-slaved to lens drive with a 66-inch radius platen and associated vacuum system, including pump, storage tank, and solenoid valve. Exposure from 1/70 to 1/700 second over complete IMC range in 1/3 f-stop increments, adjustable by command programmer.

Modified E-5. 66-inch radius focal plane and film holding rollers which may be attached to lens on scan arm with attached capping shutter. Adjustable slit on scan arm providing exposure control from 1/100 to 1/1000 second at all V/h ratios in 1/3 f-stop increments, adjustable by command programmer.

3.3.6 Platen Support

Present E-5. Monocoque, isolating focal plane from major sources of vibration and thermal disturbances.

Modified E-5. Same approach, although support tube of different shape in new space envelope.

3.3.7 Pre-Photographic Jettison

Present E-5. Nose cone covering mirror on launch must be removed prior to photography.

Modified E-5. Hatch covering mirror during launch must be removed prior to photography.

3.3.8 Film Spools

Present E-5. Large diameter, co-rotating spools. Open spool core self-contained bearing races dictated by center of gravity location required for re-entry. Slow start-up due to Iω balance wheel limitations causing some film wastage.

Modified E-5. Small diameter, counter-rotating spools. Weight, power, and vibration reduced. Fast start-up for reduced film wastage.

3.3.9 Instrumentation

Present E-5. Elaborate environmental and recovery-aid transducers in addition to camera functions.

Modified E-5. Reduced and simplified for camera functions and judicious temperature measurements.

3.3.10 Electronics

Present E-5. Germanium transistors. Platter approach with all connections soldered to cable per LMSC direction.

Modified E-5. Simplified - modular - silicone transistors thermally insensitive. The modular design will facilitate manufacture, maintenance, and troubleshooting in accordance with recent LMSC redirection on E-5.

3.3.11 Cable

Present E-5. Permanent, integral. LMSC prohibited connectors due to their reliability concern at this time.

Modified E-5 Replaceable, lighter, simpler, sectional connectors will be used to separate cable from modular electronics similar to recent redirection on E-5 by LMSC.

3.3.12 Clock

Present E-5. LMSC time signal from E-2 type clock, Itek interpolation and accumulation electronics required for indicating time at format center.

Modified E-5. Evaluate crystal oscillator to be included in camera for simplification by more straight-forward approach to problem rather than complex circuitry required for adapting clock designed for strip camera to panoramic application.

3.3.13 Power

Present E-5. 700 watts.

Modified E-5. Same or less.

3.3.14 Electrical Interface

Present E-5.

Power
Command
Telemetry
Ground Test

Modified E-5

Power - Same except 2000 cps to be eliminated.

Command - Simplified (all camera recovery commands eliminated) same orbit photographic command programmer can be used.

Telemetry - Reduced and simplified.

Ground Test - Reduced and simplified.

3.3.15 Electrical Interface Connectors

Present E-5 Nine connectors.

Modified E-5. Six connectors (five, if time signal is generated internally to the camera)

3.3.16 Internal Connectors

Present E-5. Thirty (approximately).

Modified E-5. No increase since some will be eliminated despite the fact that electronic modules will be used.

3.3.17 Weight

The comparative weights for the two systems are presented in Table 3.

Subassemblies which will be identical in both systems

Lens. 66-inch, f/5 Itek triplett

Lens Drive. Smooth oscillating 22° panoramic scan with low friction bearings and energy-conserving springs, IMC - accurate to ½ percent of commanded value from programmer.

Mirror. Lightweight 28-inch diameter aluminum flat to $^1/_{10}$ wave over full surface.

Stereo Drive. Simple 3-position cam rotates line of sight fore and aft through 30° included angle, reproducible to ½ minute of arc.

Ground Support Equipment.

Environmental Test Equipment.

Table 3 – Comparison of Weights for Present and Modified E-5

	Present		Modified	
Basic Structure	239		150	
Parachute Frame Structure	21		None	
Electronic Packages	55		30	
Electronic Cables	62		25	
Platen Support Tube	12		8	
Film Transport and Drives	36		30	
I-Omega Balance	41		None	
Lens Retraction	16		None	
Light Baffles	9		5	
Platen & Shutter Assembly or equiv.	20		20	
Re-entry Window Cover	23		None	
Vacuum System	7		None	
Window	48		None	
Lens Drives	248		248	
MV Balance	66		None	
Mirror, Drives, Support	115		110	
Mirror Thermal Radiation Shield	6		None	
Spools	66		24	
Total Camera Weight	1090 (Act)		650	
Film Weight	150	250	150	250
Total Camera/Film Weight	1240	1340	800	900
Recovery System	760*	760*	300†	500‡
Total Agena-B Launch Weight	2000	2100	1100	1400
Booster Required	Atlas	Atlas	Thor (possibly)	Atlas/Thor

*Actual E-5 recovery system for entire camera
†Estimate of recovery system for 150 lb of film
‡Estimate of recovery system for 250 lb of film (E-6 capsule).

Roll Steering. Designed to accommodate ± 30° of roll steering with IMC adjusted to compensate by command when Agena B is rotated.

3.3.19 Subassemblies which will not be used in the modified E-5 system

Window. 22-inch diameter glass flat, parallel to 1/8 wave over entire diameter. Required because of pressurization, thereby eliminating potential image degradation, reducing weight, and enhancing the reliability.

Window Cover. Motor-driven ablative-coated metal fan to protect camera window from re-entry environment.

Lens Retraction. Actuated by command to fire 4 squibs and pin pullers to release to permit motor-driven lead screws to relocate camera capsule center of gravity prior to re-entry in order to satisfy aerodynamic stability requirements.

Mirror Jettison. Actuated by 3 squibs and pin-pullers by remote command prior to re-entry for camera recovery.

Lens Lock. To center lens to enable lens retraction.

Vacuum System. Vane-pump, plenum, solenoid and valve to provide vacuum control at film platen, thereby eliminating a major source of vibration, saving weight, reducing power, and improving reliability.

APPENDIX A

CURRENT E-5 STATUS

The E-5 program consisted of diagnostic camera S/N 01 and flight cameras S/N 02 through 09. Cameras 05 through 09 are terminated.

Camera Status

S/N 01. Delivered — not flown — used as training and interface model.

S/N 02. Delivered — subjected to extensive ground test — the unit operated reliably for 75,000 lens scan cycles and transported 100,000 feet of film prior to flight. The 02 mission as programmed was approximately 5,000 photographs at 132 nautical miles.

Photo Performance. Predicted operational performance 45 L/mm.

Lab Test Results. 27 L/mm AWAR at 2:1 contrast on SO-130.

NOTE

This value is a geometrical mean over the entire format in both directions and the data in the IMC direction indicated an approximate 10 L/mm loss due to test equipment limitations at the time. Thus, the camera lab test results were actually 35 L/mm at 2:1 contrast. In addition, ap- [redacted]

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Reliability. It is significant to note that the mean time between camera malfunctions exceeded flight requirements except for those malfunctions directly attributable to test setups, operators or sources external to the camera.

S/N 03. Delivered — subjected to extensive ground test. The unit operated reliably for 47,114 lens scan cycles and transported 82,000 feet of film prior to flight. The 03 mission is programmed for approximately 5000 photographs at 132 nautical miles.

Photo Performance. Predicted operational resolution 50 L/mm.

Itek Boston Test Summary. (SO-132 Film)

Type of Test	Exposure	Contrast	Resolution
Static — 1 atmos.	Strobe	High	108 L/mm peak and 85 L/mm over lens field angle
Dynamic — 1/2 atmos.	1/300 sec	High	70 L/mm
Semi-dynamic* -1 atmos.	1/1000 sec	High	75 L/mm
Semi-dynamic* -1 atmos.	1/1000 sec	2:1	70 L/mm
Dynamic — 1/2 atmos.	1/300 sec	2:1	65 L/mm

Itek Palo Alto Test Summary. Improved platen focus was obtained and shimmed prior to further testing. (SO-130 Film was used.)

Type of Test	Exposure	Contrast	Resolution
Static	1/250 sec	2:1	43 L/mm
Dynamic	1/250 sec	2:1	37 L/mm
Dynamic	1/250 sec	High	45 L/mm

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[redacted]

*All camera systems functioning except film transport for testing convenience.

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S/N 04. Unit in final acceptance test. Performance improvement over 03 anticipated. Estimated operational resolution 55-60 L/mm.

Status of Remaining Units

Unit	Completion Part	Subassembly	Lens	Mirror	Test Film, Feet	Est. Oper. Resolution, L/mm
SN 05	100%	95%	Comp.	Comp.	17,000	60- 70 L/mm*
SN 06	95%	75%	80%[1]	95%[5]	28,000	65- 75 L/mm*
SN 07	90%	40%	65%[2]	70%[6]	[8]	85- 90 L/mm
SN 08	75%	20%	25%[3]	[7]	[8]	90-100 L/mm
SN 09	70%	5%	[4]	[7]	[8]	90-100 L/mm

NOTES:

1. Six lens elements totally completed and awaiting assembly. The cell and rings are approximately 85% complete with less than 10 days of machining required. The total lens assembly is approximately 4 weeks away from completion including all optical tests.

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[redacted] The cell and [redacted] required for [redacted] completed.

[redacted] hand and avail- [redacted] the lens [redacted] optical test.

[redacted] 75% [redacted] the 10th of [redacted] and was [redacted], and

5. Fabrication complete except for coating.
6. Fabrication complete except for final polishing and coating.
7. The mirror casting has been ordered. The mirror can be completed in 12 weeks.
8. Film for Itek test and LMSC test and flight ordered in 17,000-foot lengths.

APPENDIX B

PHOTO PERFORMANCE

Factors affecting the overall performance of the camera system are static lens-film resolving power, other optical degradation factors and smear arising from uncompensated image motion and vibration.

Table B-1 lists the sources of image blur based on the most current estimates available for the Agena B vehicle orbit stabilization performance and current 101B cameras. Since these effects are random in sign and magnitude they were combined on a root-sum-squared basis to give a total image blur velocity of 660 ft per sec at 132 nautical miles for E-5. The modified camera has approximately 40% less inherent vibration resulting in a total camera/vehicle image blur velocity of 550 ft per sec for 15% less total system blur offering a resolution improvement.

Exposure time for both SO-130 and SO-132 was determined as a function of solar altitude and combined with the E-5 blur velocity to give the amount of blur at the ground. The blur was in turn combined on a RSS basis with static ground resolved distance figures for the lens-film system.

Figs. B-1 through B-4 show the anticipated resolution at both 2:1 and medium contrast and ground resolved distance capabilities as a function of solar altitude. (The curves are "staircased" since discrete shutter slits were assumed for proper exposure.) The f/5 peak and AWAR lens-film data are those for the S/N 06 lens-film combinations of the 101B program as measured at 2:1 and medium contrast. It should be noted that the illumination for selecting exposure is based on hazy conditions. If very clear conditions are encountered during actual missions, target contrast will be greater giving better resolution. Exposure between "Hazy" and "Clear" can be compensated for in controlled processing of the recovered film.

Fig. B-5 shows the variation in solar altitude or horizontal plane illumi-nance with time-of-year and geographic location at noon.

Table B-1. Image Motion Factors

Source of Error	Maximum Error	Blur Velocity, f/s	$(V_\epsilon)^2 \times 10^{-4}$
Inaccuracy in predicting IMC	0.5%	125	1.563
Inaccuracy in generating IMC (inc. scan velocity error)	0.9%	220	4.840
Vehicle Yaw Error	0.8°	340	11.560
Vehicle Roll Error	1.0°	50	0.250
Vehicle Pitch Error	1.0°	30	0.09
Vehicle Roll Rate	40°/hr	155	2.403
Vehicle Pitch Rate	40° hr	155	2.403
Vehicle Yaw Rate	60°/hr	45	0.203
Alignment in Yaw	0.1°	40	0.160
Yaw rate induced by spool momentum unbalance	48°/hr	35	0.123

	Present E-5		Modified E-5		
Vibration	450 f/s	450	20.25	260 f/s	6.8
Lens Drive	5%	20		20 f/s	
Film Transport	28%	125		75 f/s	
Shutter	5%	20		20 f/s	
I_ω	32%	145		0	
MV	15%	60		0	
Vacuum Pump	10%	40		0	
Metering Drive	5%	20		20 f/s	
			$V_\epsilon^2 = 43.85 \times 10^4$		$V_\epsilon^2 = 30.35 \times 10^4$
			RSS (V_ϵ) = 660 ft/sec		RSS (V_ϵ) = 550 ft/sec

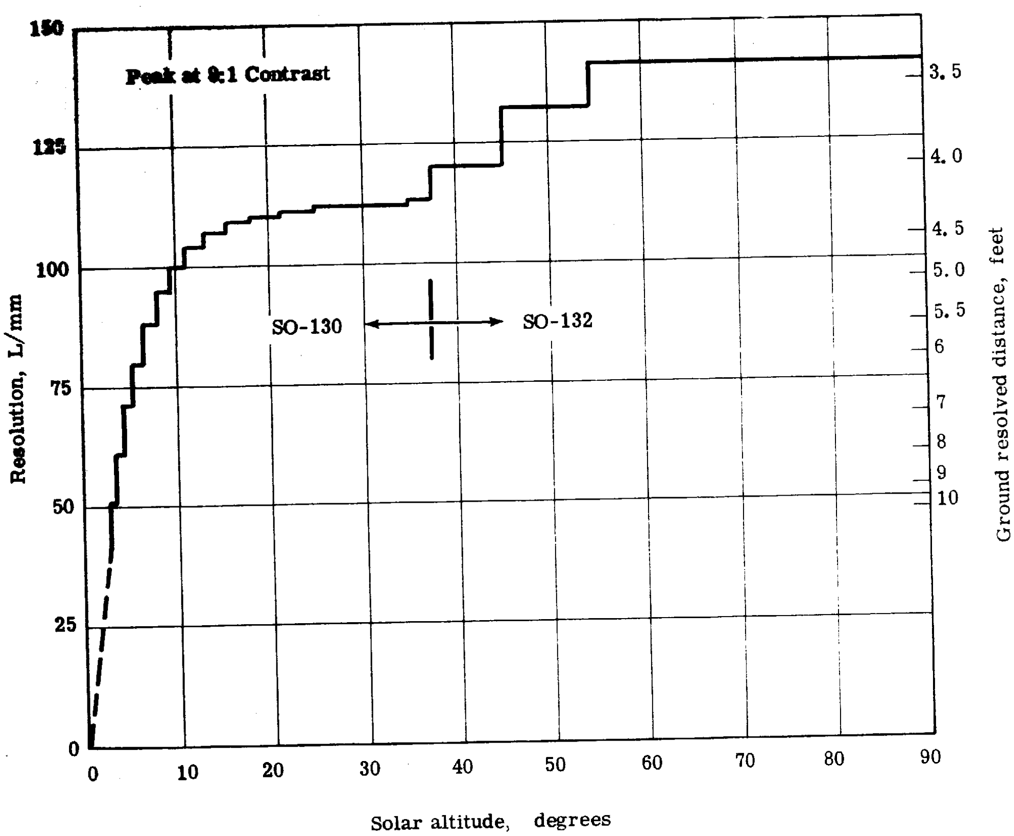

Fig. B-1 – Resolution vs solar altitude at 132 n. mi. for a 660 f/s IMC error

Peak lens/film resolution at 8:1 contrast:

SO-130: 113 L/mm
SO-132: 165 L/mm

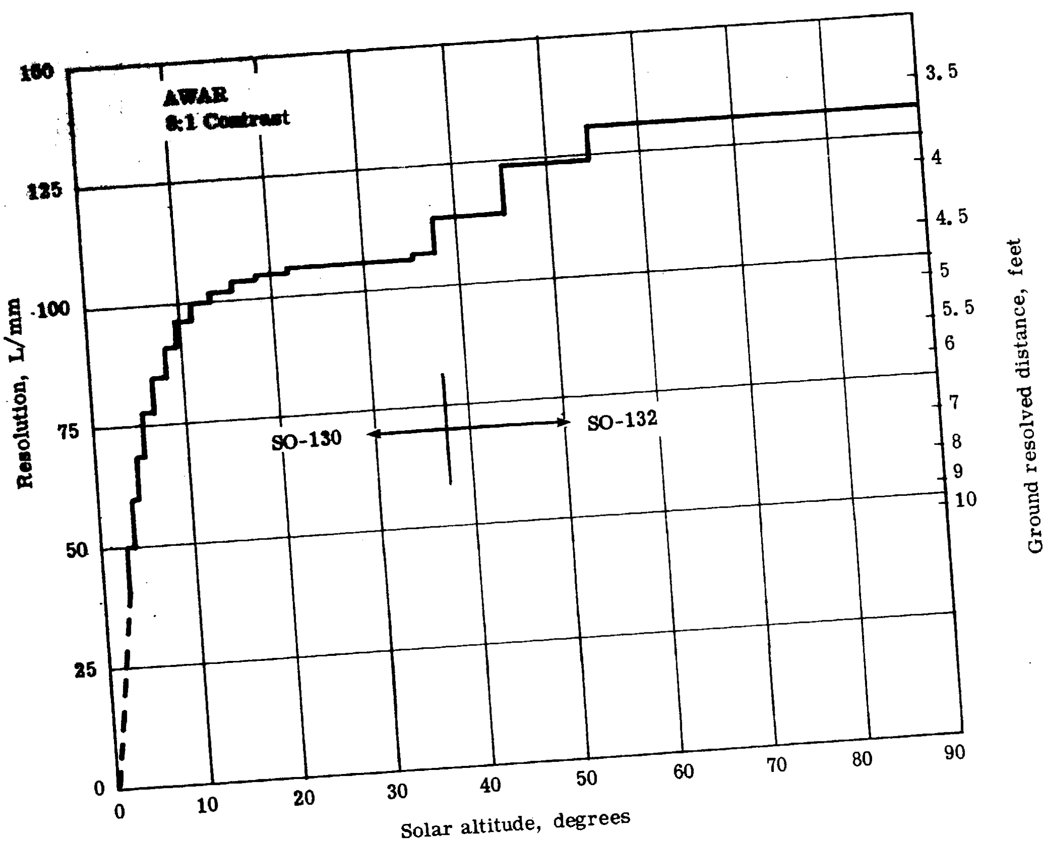

Fig. B-2 – Resolution vs solar altitude at 132 n. mi. for a 660 f/s IMC error

AWAR lens/film resolution at 8:1 contrast

SO-130: 107 L/mm

SO-132: 150 L/mm

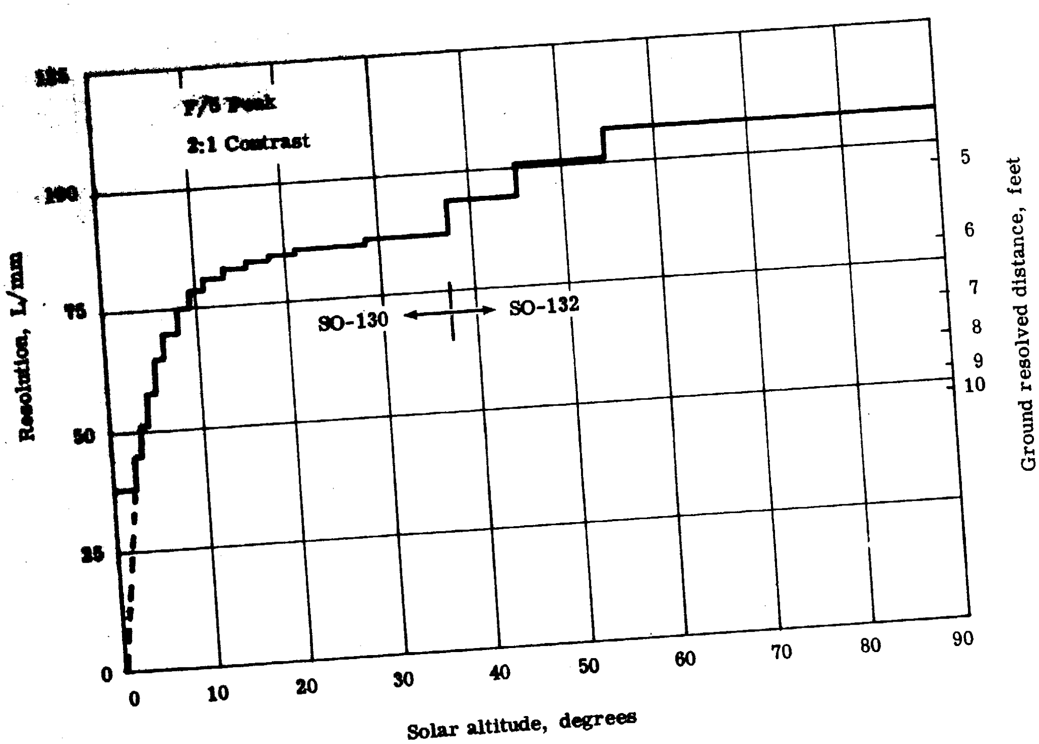

Fig. B-3 – Resolution vs solar altitude for an f/5 system at 132 n. mi. with 110% V/h having an IMC error of 660 f/s

Peak lens/film resolution at 2:1 contrast

SO-130: 87 L/mm
SO-132: 121 L/mm

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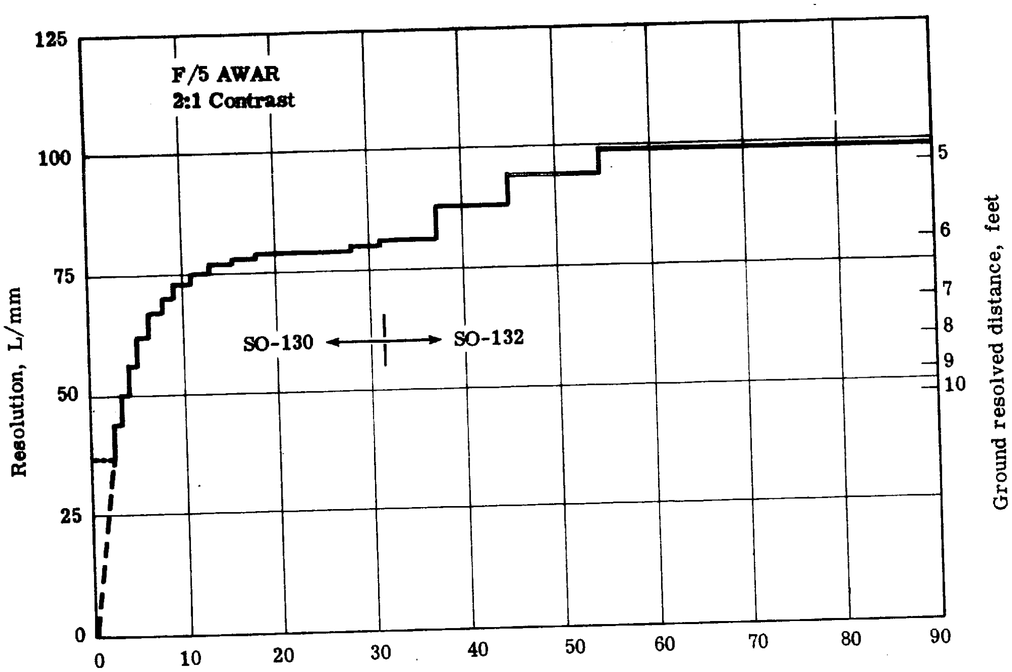

Fig. B-4 – Resolution vs solar altitude for an f/5 system at 132 n. mi. with 116% V/h having an IMC error of 660 f/s

AWAR Lens/film resolution at 2:1 contrast

SO-130: 80 L/mm
SO-132: 110 L/mm

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34

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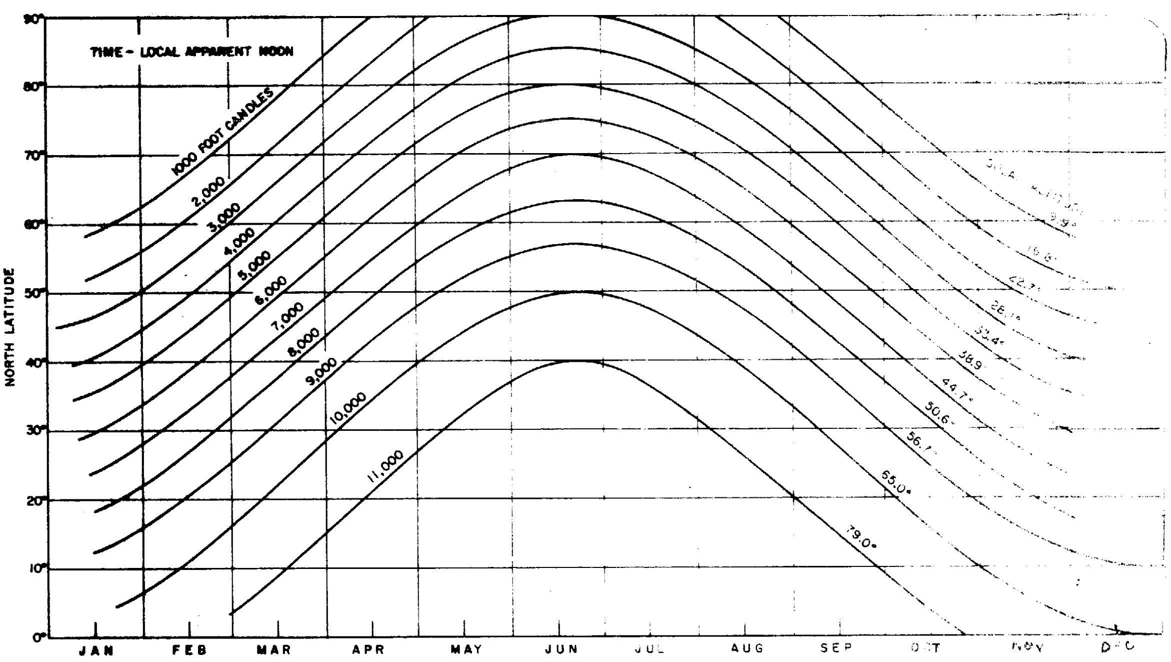

Fig. B-5 — Plots of constant solar horizontal plane illuminance for north latitude and time of year

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PERSONNEL RESUMES

The resumes of the senior, E-5 engineering personnel who will be assigned to this program are presented on the following pages.

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Next 11 Page(s) In Document Exempt

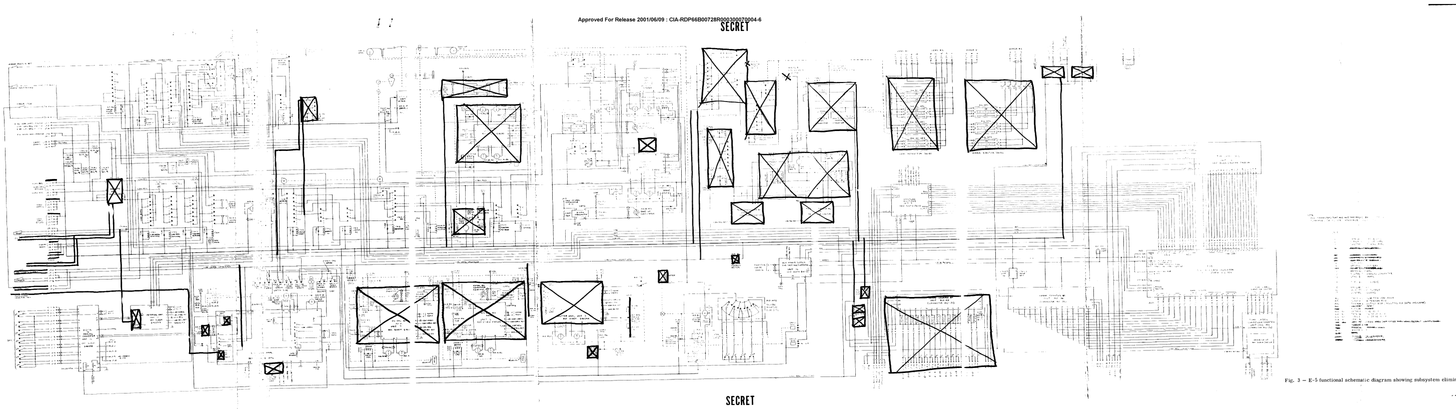

Fig. 3 — E-5 functional schematic diagram showing subsystem eliminated